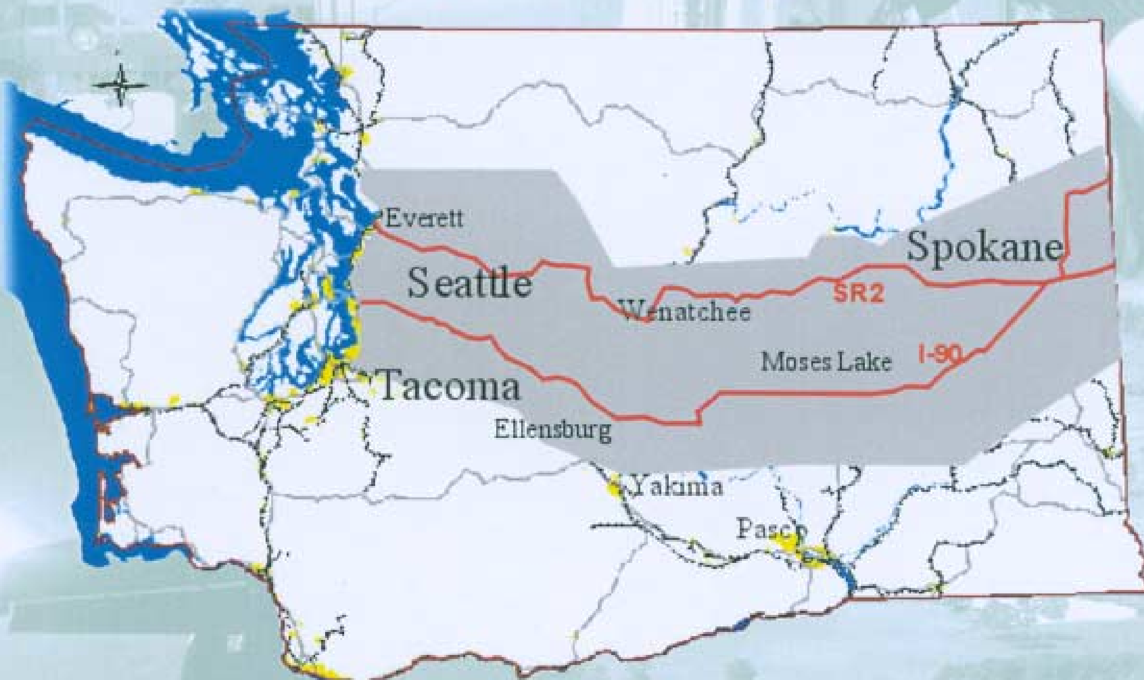
Washington State
Department of Transportation

Cross-Cascades Corridor Analysis Project



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Preface

The Cross-Cascades Corridor model provides a unique tool for forecasting transportation demand and understanding how our transportation systems and the economy interact. Begun as a modeling effort of the Seattle to Spokane corridor, the project has become the basis for a new approach to corridor and statewide modeling across the state. This report framework documents the effort and outlines key considerations for future model development. There are three separate documents contained in this framework that summarize and describe the modeling effort developed as part of the Cross-Cascades Corridor Analysis Project.

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These documents and supporting material require the use of Adobe Acrobat software to read and access other files via the navigation bar located on each page, in either the left or right hand side margin.

Each of these reports is explained in greater detail below. You can navigate inside the Summary Report, Model Documentation, or User Guide using the page up and down arrows. You can also enter another document by clicking on the document name at the bottom of the navigation bar. If you would like to exit the document framework altogether or return to the cover page, use the report cover icon at the bottom of the page.

Summary Report

The Summary Report provides an overview of the purpose of the project and a general description of the Cross-Cascades Corridor. The report also serves as an introduction to the model, it's structure, how it represents the corridor, the model components, how it was tested, and a demonstration of how the model estimates the effects of different events or policy decision scenarios on the corridor. Suggestions for future modeling efforts are also offered in this section.

The Summary Report has also been produced in a print-friendly format. Material contained in the printed report is the same as that shown here. To receive copies of the printed version of the document, visit the project web site at http://www.wsdot.wa.gov/ppsc/cascadesx/Cross%20Cascades%20Corridor%20Analysis%20Web/index.htm, or contact WSDOT's Transportation Planning Office by mail at Transportation Building, PO Box 47370, Olympia, WA 98504-7370, or by telephone at (360) 705-7958.

Model Documentation

The Model Documentation report provides greater deal about the inner-workings and inputs to each of the Cross-Cascades Corridor model's components - the Land Use Model, Transport Model, and Interface Model. Calibration or testing methods used during the model development effort, and the scenarios used to demonstrate the model's potential, are also described in greater detail. In some cases, topics covered in the Model Documentation report are supported with another, more detailed page that is often accompanied by an explanatory spreadsheet or example of model output. A site map for this document is available in the navigation bar on each page.

User Guide

The User Guide is designed to support the user when installing and running the MEPLAN model. This report covers the model's basic structure and the critical files that were used in its development. This document also discusses the ArcView interface and the model development project references.

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Washington State Department of Transportation

Cross-Cascades Corridor Analysis Project

WSDOT - Transportation Planning Office

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Purpose & Background

The Washington State Department of Transportation (WSDOT) contracted with HDR Engineering, Inc., to develop a travel demand forecast that is capable of producing interregional forecasts and analyses across the full length of the Cross-Cascades Corridor (Figure 1) incorporating all transportation modes, and with the ability to test alternative scenarios for transportation development.

The modeling approach selected is known generically as Spatial Input-Output methodology. It distributes household and economic activity across zones, uses links and nodes of a transportation network to connect the zones and model the transportation system, and then calculates transportation flows on the network. It uses an input-output (I-O) structure of the economy to simulate economic transactions that generate transportation activity. In future years, the spatial allocation of economic activity, and thus trip flows, is influenced by the attributes of the transport network in previous years. Thus, the model is dynamic both with respect to land use and transportation.

The spatial I-O approach was selected from among several modeling options presented to WSDOT and MPO modelers from throughout the State. Other options included a four-step traffic model, trip tables calculated through an entropy maximization method, microsimulation and linear programming. Micro simulation and linear programming were not chosen because they would not be able to address the issues present in the corridor within the time frame available. The spatial I-O approach was determined to be superior to the other two approaches because of its ability to address more policy issues, particularly those associated with distribution of economic activity.

In selecting the spatial I-O approach the project team recognized that it would have to be developed on a very fast track and that some desirable elements of the model would have to be skipped in the first round. Further, it was recognized that the model could not be fully tested within the available time frame. As a result of these decisions it is recognized that the model in its present form will demonstrate the value of the approach and provide a tool that can be further developed in later corridor and statewide transportation studies.

The model will aid WSDOT in its transportation planning efforts and enable WSDOT to better tailor its services to meet transportation needs of the state. The model provides WSDOT with a tool for estimating not only the issues within this corridor, but also forms the basis for a statewide travel demand model. This initial application of the model provides a demonstration of potential sketch-planning evaluation of corridor issues in a real-world

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environment. The application shows how this model approach incorporates economic and demographic variables, with the potential to incorporate land use directly in future updates of the model. This chosen modeling approach will aid WSDOT in its ongoing transportation planning efforts and assessment of policy questions, allowing WSDOT to better tailor its services to meet the transportation needs of the state.

The purpose of this report is to document model development and to assist WSDOT in further model development, eventually allowing WSDOT staff to run their own scenarios and revise the model for use in other corridors. This summary overview is intended to introduce the reader to the model framework as implemented for the Cross-Cascades Corridor Analysis Project, identify key data sources and assumptions, review model calibration and scenario testing, and document recommendations for future model improvements.

Model Overview

An overview of the model is shown in Figure 2, referred to as "The Hunt Diagram." The model has three major components:

- **Land Use** describes economic, household and land use characteristics and the interaction between them. Key elements of the land use component:
    - The I-O table estimates the amount of activity generated throughout the Washington State economy as a result of output of each economic sector;
    - The estimate of "exogenous demand" is the amount of export activity and other activities, not tied to economic production in any sector; and
    - This initial version of the model does not contain land prices, which reflect the impact of growth on production costs and household costs. Land prices may be added to future updates of the model.

- **Transport** describes the transportation network in terms of:
    - Transport flows associated with economic activities
    - Networks describing how trips travel through the network, influenced by cost and capacity constraints, and
    - Links describing how each mode connects to other modes.

- The **Interface Model** relates economic and household activities to transportation flows and create the interactive capabilities of the model:
  - o Relating economic and household activities to transport flows, and
  - o Relating transportation costs and accessibility to economic and household activity.

MEPLAN

The software used to run the model is MEPLAN, developed and distributed by ME&P of Cambridge, UK. The structure of the MEPLAN model is shown in Figure 3. The structure parallels the Hunt Diagram and MEPLAN represents:

- The Land Use Model component as LASA and LASB, processing economic and household data, including the ninput-output table and generating output data;
- The Transport Assignment Model as TASA and TASB, containing transportation network and flow information; and
- The Interface Model as FREDA, relating land use and economic volumes.

Key outputs generated by MEPLAN include:

- Land use and economic outputs, in terms of zonal characteristics (employment and households);
- Transportation volumes including O-D transportation flow volumes, network link volumes, congested travel times, network data and other statistics; and
- Interface model including disutilities (costs) of transportation between zone pairs, flow volumes and evaluation statistics.

It is noted that the MEPLAN software is intended to model availability and demand for land, including changes in land prices. That component was not included in this initial version of the Cross-Cascades Corridor model development because of the cost of collecting the data and the limited time available for development of the model. It could be included in future updates.

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Outputs of the model include:

- Average daily traffic volumes for the average weekday for the corridor;
- Mode splits between highway, rail, intercity bus and air for the corridor;
- Future household allocation by income group and zone; and
- Future employment allocation by industry and zone.

Because of the interactive nature of the model it can be used to test:

- Impact of economic and demographic changes on transport;
- Impact of transport improvements on the economy and population; and
- Impact of policy decisions that change the availability or cost of transportation.

The remainder of this summary describes the three basic components of the model in more detail as applied in this study of the Cross-Cascades Corridor. The report is organized by the Hunt Diagram and contains references to the MEPLAN model components (Figure 3).

Land Use Model

Consuming and Producing Factors (Economic Activity) Table

Factor Definitions

Factors are defined (in ULP [1]) as the chosen set of industry sectors and household income groups. Ten industry sectors were used in the Cross-Cascades Corridor Analysis Project based on employment data supplied by the Labor Market and Employment Analysis (LMEA) unit of Washington's Employment Security Department:

- Agriculture, forestry and fishing;
- Mining;
- Construction;
- Manufacturing;
- Transport, communications and public utilities (TCPU);
- Wholesale trade;
- Retail trade;
- Finance insurance and real estate (FIRE);
- Services; and
- Government

Input-output coefficients relating consumption and production were taken from the IMPLAN I-O model for Washington State. A number of assumptions had to be made to adjust the IMPLAN balanced I-O table for use the MEPLAN model structure. The most significant of these were:

- Demarginalizing retail trade so households consume from retail via wholesale, rather than directly form each industry;
- Reducing the number of export, household income, financial processing and government categories; and
- Converting the trade flows from dollars to employees or households based on productivity factors.

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Future models could use more detailed economic sectors based on available input-output and employment data.

Households were broken into four roughly equal income groups:

- $0 - 17,499 (26 percent of 1990 Washington State households)
- $17,500 - 29,999 (22 percent)
- $30,000 - 49,999 (28 percent)
- greater than $50,000 (24 percent)

All data were from 1998 or adjusted to that year to provide a consistent base year.

Zones

The model uses 61 zones, 54 in Washington, 1 in Idaho, and 6 external. Washington and Idaho zones (Figure 4) were generally organized by county boundaries. Seven counties within the corridor were further subdivided into 2 to 4 zones. These included:

- Adams
- Chelan
- Douglas
- Grant
- King
- Kittitas
- Lincoln

Spokane County was not subdivided. The Puget Sound Region was divided into five zones (3 in King County, and one each in Snohomish County and Pierce County) based on the regional transport network.

External zones (Figure 5)were chosen to reflect major travel flows to and from Washington State.

Only the model outputs with respect to the Cross-Cascades Corridor itself are considered to be useful in the current application. The other Washington State zones are intended to provide a buffer between the external zones and the corridor itself in order to increase the accuracy of flows within the corridor. Zones are input into MEPLAN in the ULP[2] file. Future model development will likely lead to a larger set of smaller zones of a more consistent size across the whole state. To provide an adequate buffer, internal zones may also extend into Oregon, Idaho, British Columbia, and Alberta.

Future versions of the model, particularly as they are applied to other corridors, should adjust the zonal structure as appropriate for the region under consideration. In addition, with more time for data collection and model specification it may be appropriate to increase the number of zones in a corridor to create more refined estimates of transport flows.

Demographic Inputs by Zone

In the base year, the model was constrained to achieve the official Washington State employment and household activity by zone and input into the model via ULC[1] file. For future years, no constraint was imposed in the initial runs.

Households by zone. County level 1998 households were developed from population data by county and household size data from the Washington State Population Survey. County level households were split into smaller sub-county zones using 1990 US Census tract household data. King County was split using PSRC breakdowns.

Total households by zone were divided into four income groups, as described earlier, based on data from the 1990 Census. Household densities by zone are shown in Figure 6a.

In future updates of the model, the availability of 2000 Census data will improve the ease and accuracy of household estimates by zone.

Employment by industry by place of work, by zone. County-level 1998 employment by major industry sector were developed from covered employment data and adjusted by industry to reflect total employment. In making the adjustment, BEA data on total employment by industry and LMEA studies of covered and non-covered employment were used. The BEA data could not be used directly because it is based on place of residence rather the place of work as required by the MEPLAN model.

As with household data, total employment by industry by county, was allocated to sub-county zones based on 1990 census data. Census values for total employment data by place of residence were used. Employment densities by zone in 1998 are shown in Figure 6b.

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MEPLAN Coefficients

MEPLAN coefficients represent economic activity linkages in the Washington State economy. In MEPLAN, the coefficients describe the amount of each type of employee and household factor required to produce a single unit of each factor. They define the amount of input and output of each industry and household that are later converted to trips on the transport network. MEPLAN coefficients are derived from the balanced IMPLAN Input-Output table in units of employee/ households per employee/household (in ULP[3]). Kootenai, ID was assumed to follow the Washington State-based economic coefficients.

Baseyear Exogenous Production

In the MEPLAN model, exogenous production is defined as that production which is related to export sales or sales to households whose income is not derived from production within the interindustry matrix (i.e., income of retirees, unemployed or investment income). Percentages by industry are shown in Table 1, Exogenous Production by Factor. I-O data processing identified at a statewide level the following Washington State employees (by industry) and households (by income group) that are working for exogenous production.

Table 1 – Exogenous Production by Factor

Factor	Total	Exogenous	Percent Exogenous
Agriculture	122,398	97,432	80%
Mining	3,380	282	8%
Construction	155,869	42,289	27%
Manufacturing	407,455	185,695	46%
TCPU	145,334	59,150	41%
Wholesale Trade	163,227	15,759	10%
Retail Trade	506,920	28,023	6%
FIRE	143,288	47,205	33%
Services	761,001	233,870	31%
Government	501,340	229,043	46%
$0-15K Household Income	640,496	340,219	53%
$30-50K Household Income	544,471	127,394	23%
$50+K Household Income	595,022	54,754	9%
Imports	-	1,660	-

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In general, exogenous production was distributed to zones based on 1990 zone-level counts of "exogenous households" and total employment, as shown in Figure 7. Employment data was also reviewed to identify industries within a major industry category that were both predominantly export-oriented and highly concentrated in a few zones. Only one case was found in which there was also sufficient data to reallocate exogenous employment. That was in regard to aircraft manufacturing, which is highly concentrated in the Puget Sound area. In this case, the amount of employment representing aircraft manufacturing in those zones was automatically assumed to be 95% export. The remaining exogenous employment was then allocated among all zones in proportion to total employment.

In future models, the use of more economic sectors in the I-O model, or the collection of more employment data could be used to make a more detailed allocation of exogenous employment.

Future Growth

Future year growth is generated by growth in exogenous demand. The Office of Financial Management (OFM) State-level Covered Employment in Washington State for 2000, 2005, 2010, 2015, 2020 (adjusted by base year non-covered employment ratios) was used to estimate exogenous demand. A constant growth rate for all factors, as shown by year in Table 2, was applied. Spatial allocation of the future year economic activity by zone is then estimated by the model.

Table 2 – Assumed Exogenous Production Growth by Year

Year	Growth from Previous Year
2001	5.85%
2004	4.36%
2007	3.90%
2010	3.45%
2013	3.80%
2017	3.67%
2019	3.49%

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Transport Model

Transport Flows Table

Flow Types

The model defines 11 transport flow types (in UTF [1-2], as shown in the Hunt Diagram:

- Four personal passenger (commuter, shopping, visit friends & relatives, and recreation/other);
- Two business passenger (services and business promotion);
- Three freight (low, medium, high value-to-weight); and
- Two external truck trip types (external-external, external-internal).

Personal passenger flows are in units of trips per household. Business passenger flows are in units of trips per employee and vary by industry for service and business promotion.

Value-to-weight freight categories allow groupings reflective of mode split behavior. These were defined as:

- Low value-to-weight = < $3000 per ton
- Medium value-to-weight = $3001-5000 per ton
- High value-to-weight = > $5000 per ton

Additionally, the following externally generated truck trips were modeled. These trips are based on demands outside the study area (for which the model does not determine mode split behavior). Future model development could include the externally-generated trips of other modes. These are defined as:

- External-to-internal truck trips
- External-to-external truck trips

User Modes Table

User Mode Types

The model defines nine user modes in UTF[3] and as described in the Hunt Diagram:

- Air freight;
- Rail freight;
- Heavy truck freight;
- Medium truck freight;
- Air passenger;
- Amtrak (rail passenger);
- Coach (bus passenger);
- Private auto; and
- Work auto.

Private and work auto also include van and light trucks for personal and business purposes.

Truck types are consistent with the PSRC FASTruck study. The definitions rely primarily on weight, with truck/trailer type classifications added to correlate with Quick Response Freight Manual categories:

- Light trucks are defined as 4 or more tires, 2 axles and less than 16,000 lbs gross vehicle weight (GVW);
- Medium trucks are defined as single-unit, 6 or more tires, 2-4 axles and up to 52,000 lbs GVW; and
- Heavy trucks are defined as double or triple-unit, combinations, of 5 or more axles and over 52,000 lbs GVW.

The medium and heavy categories correlate directly with WSDOT truck traffic count categories, matching single and double/triple-unit trucks, respectively. WSDOT data groups light trucks with passenger cars.

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Mode Choice

In the model, mode choice is calculated based on monetary values of time, distance and cost. This mode split disutility function structure and coefficients are defined in UTF with cost functions in UTF and UTM. Costs (disutility) are related to mode choice through a nested logit function with linear utility, defined in MEPLAN UTF[5] file. The function distributes trips stochastically rather than assigning all trips to the least cost route.

Passenger Cost Functions. Using O-D fare and distance information for coach (Greyhound and Northwest Trailways), rail (Amtrak), and airlines, the following passenger fare cost functions were calculated using linear regression. These are shown in Table 3. Other functional forms were also considered, but had a less statistically significant or less intuitive fit.

Table 3 – Passenger Fare Functions

Mode	Terminal Cost	Minimum	Constant	Distance Rate ($/pax-mile)
Coach	NA	$5	$5.53	$0.0874
Amtrak	NA	$5	$5.47	$0.1348
Air Passenger	All	$40	$54.68	$0.0777
	Seattle		-$22.51	
	Southern Idaho, Eastern Oregon, Southwest		-$11.32	
	Externals		+$33.88	

For the private drive mode, a distance cost of $0.06 per mile and value of time of $15.00/hour were assumed. Business/work drive mode assumed slightly higher $0.10 per mile and $18.80 per hour. Parking costs at Seattle and Spokane airports were included because of the large rate disparity.

For higher-density urban applications, other parking costs should be added.

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Freight Cost Functions. Freight costs were assumed to consist of a distance-based charge (paid by the shipper to the carrier), a time cost, and a terminal handling fee. A range of distance (per ton-mile) costs were collected from various sources (NCHRP #388, Port of Portland Study, Horizon Air Freight). Time costs were assumed to be:

- $18.80/hour work drive
- $16.50/hour commercial driver

Terminal handling costs use the distance-based rates and assume a $75 fee for a local (20-mile) medium truck trip. This resulted in a terminal handling cost of $20.50 for medium trucks (from Port of Portland Study for containers). The handling cost was increased by 25 percent for heavy trucks. Rail handling fees were calculated assuming that medium truck and rail are competitive at 250 miles (per WSDOT Rail Office). The handling costs used in the model are shown in Table 4.

Table 4 - Freight Rate Functions

Mode	Terminal Cost	Distance Rate ($/ton-mile) Range (including terminal cost)	Distance Rate ($/ton-mile) Assumed
Work Drive/ Light Truck	$0	$0.04-$0.10/ton-mile	$0.10
Medium Truck	$20.50	$1.25-2.50/mile	$0.08
Heavy Truck	$25.63		$0.10
Rail Freight	$37.50	$0.02-$0.04/ton-mile $2.20-2.73/mile	$0.03
Air Freight	$70.00	$4.90-7.50/ton-mile	$3.00

Travel States

MEPLAN refers to travel states as Network Modes, which are defined in UTM [1] and listed in the Hunt Diagram. They refer to the various activities that make up the trips defined as mode choices. An intercity bus trip, for instance, involves a trip to the terminal, a wait at the terminal, the actual bus travel, a wait at the destination terminal, and a trip to the actual destination. Fifteen states were defined to represent the in-transit and station/terminal

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activities for passengers and freight. The states available for each mode, input to the model in the UTF[3] file, reflects the "s" values in the Hunt Diagram.

Driving was split into private and work to reflect different values of time. Coach (bus) was split into specific routes/services within corridor and implicit service anywhere outside of the corridor.

In future model development it may be desirable to distinguish between work and personal trips for rail and air as well and split out work auto from light trucks. It may also be appropriate to model more completely the terminal and transfer logistics of the freight modes.

Transport Network Links and Nodes

All baseyear and future year physical networks (roadways, railways, airways) are defined as sets of links and nodes. They are input into the following MEPLAN files:

UTN[1] Baseyear physical network links, and future year new/deleted links (assumptions are in: Highway Network 5-15-01.xls, Rail Network 5-15-01.xls, AirNetwork.xls)

UTN[2] Future year link attribute modifications (scenario assumptions are in: "Future Year Hwy Network Changes.xls", "SR2 Hwy Scenario.xls")

UTN[4] intrazonal nodes, must be direct link from centroid to this node, and intrazonal trips will find a path to return to the centroid. Typically, this node was 1-2 links away from the centroid.

Links describe how the 15 "States", or Network Modes connect for any given trip. They are defined in UTM [2] and listed in the Hunt Diagram. The links used to connect each user mode to the zone centroids are illustrated in Figure 8. In all, 13 link types were defined to represent the process of travel between zones. Roads, railways, and airways represent links on physical networks. Coach, Amtrak, and air passenger services operate on top of these physical networks. Truck, rail and air freight terminals model intermodal connections, and allow the inclusion of terminal transfer costs (parking and freight handling, see costs). Similarly, road station connectors give passenger access to the passenger services (bus, rail, air) and allow the inclusion of parking fees. Wait links account for passenger service delays reflective of scheduled service frequencies. The physical network links include attributes of link length, link charge, link time or speed, and link capacity. Public transit services (air passenger, coach, Amtrak) required additional attributes of vehicle capacity and headway. The units of the coded link attributes are defined in the MEPLAN UTB file, along with the conversions to common units of minutes and miles.

Nodes, defined in UTC include attributes of geographic location (only used by a graphical interface such as Network Tool or ArcView). In the Cross-Cascades Corridor model, two node types were defined: centroids and other. Nodes were defined in the format ZZ.NNXX; where:

ZZ= the TAZ number in which the node is located,
NN= uniquely identify the node within a TAZ, where:
00 = Zone Centroids
01-49 = Highway nodes (typically 01 connects to the centroid)
50-74 = Railway nodes, including rail stations
75 = Airports
80-81 = Truck Terminals
90 = Port
XX= special identifiers, typically 00 (MEPLAN adds identifies here when creating service links)

Roadways. Within the corridor itself, all state highways are included in the road network (Figure 9). The remainder of Washington State includes all Highways of Statewide Significance as defined in the State Highway System Plan. Highway system nodes were taken from WSDOT's emme/2 model. A distinction was made between interstate and highway roadway links (different link types), reflecting level of road service quality.

Attributes of the highway links were taken from the Travel Delay Methodology, using the following aggregation functions:

- Length (mi) = sum of MP
- Charge ($)= sum of charges ($0 except for ferry tolls)
- Speed (mph) = average speed of aggregated links
- Capacity (veh/hr) = minimum capacity of aggregated links

Special links were created for ferries, international barge link to Tokyo (zone 61), and Columbia River barge. Surrogate costs and speeds were applied to approximate the actual ttributes of traversing these links.

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In determining the impact of traffic volumes on available highway capacity, the equivalency factors shown in Table 5, were used to relate vehicles of different sizes as passenger car equivalents.

Table 5 – Equivalent Vehicle Ratios

User Mode	Passenger Car Equivalent
Light Truck	1.5
Medium Truck	2.0
Heavy Truck	2.5
Coach Bus	2.5

Railroads. The model includes all Mainline Class I railroads in Washington State. Links and nodes were taken from CTA Rail Network. Attributes for rail freight operations were drawn from various sources and include:

- Length (mi)
- Time (hrs)
- Capacity (gross ton-miles/mile/year)

Freight rail access was allowed at the following cities, internally [[x]]:

- Spokane
- Port of Seattle for export overseas
- Port of Tacoma for export overseas

No Amtrak or freight rail connections were assumed to the external zones with the centroids of Dallas, TX (zone 59) Fernie, BC (zone 57) or Tokyo (zone 61). However, Tokyo rail links were constructed to Tokyo as surrogates for rail access via the ports of Seattle and Tacoma.

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Airways. The model includes seven primary corridor freight and/or passenger airports within or adjacent to the Cross-Cascades Corridor, each defined as a separate node:

- Seattle (SEA);
- Spokane (GEG);
- Wenatchee (EAT), passenger only;
- Yakima (YKM), passenger only;
- Pasco (PSC), passenger only; and
- Boeing Field (BFI), freight only.

Passenger airports are assumed to access external zones if nonstop or non-Seattle one-stop service was provided in 2001. Nonstop service would have the advantage of shorter flight distance and time over connecting service. Due to lack of data, Boeing Field non-stop freight destinations was assumed to have the same routes, length, and time as Sea-Tac destinations.

Airways are defined as links and include:

- Length (great circle distance in nautical miles) following connecting routes if non-stop is not available.
- Time (hours) equal to scheduled passenger flight time or connecting route time, including layover.

For the airway system, capacity is defined at the node. The airway network is shown in Figure 10.

Future model development could expand the airways detail to cover the additional primary airports within state, possibly expanding to Vancouver, BC and Portland airports, as well as updating Boeing Field routes/attributes.

Passenger Services

Passenger services were defined for coach (intercity bus), Amtrak (intercity rail) and air. All base year and future year passenger services are defined in the MEPLAN UTN[2] file and operate on the physical networks just described. Separate link-node networks are derived from the UTN[2] route data during MEPLAN pre-processing of the transport sub-model (TASB).

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Air Passenger Service. Air passenger service was assumed at all airports except Boeing Field. Attribute data used includes distance, time and speed between stations, aircraft capacity, and service frequencies. The model assumes the same external centroid destination for each Washington airport origin. If no direct flight exists, attributes from non-Sea-Tac were used. Cities chosen to represent the external zones are shown in Table 6.

Table 6 – Air Services from Cross-Cascades Corridor

Zone	City	Non-Stop	Washington State Origin
56	Western Canada	Vancouver, BC, Canada	Seattle
57	Eastern Canada	Calgary, BC, Canada	Seattle, Spokane
58	Northern Idaho, East	Minneapolis/ St. Paul, MN	Seattle, Spokane
59	Southern Idaho, Eastern Oregon, Southwest	Dallas/ Ft. Worth, TX	Seattle
60	Western California	San Francisco Bay Area, CA	Seattle
61	Non-US	Tokoyo, Japan	Seattle

Coach Service (Greyhound & Northwest Trailways). Public transit network data collected within the Cross-Cascades Corridor includes station location, distance, time and speed between stations derived from published schedules, vehicle capacity, and service frequencies. This initial model included only those schedules within the corridor.

Future models may expand to the entire state.

Amtrak Service. Amtrak service from Spokane to Seattle and from Spokane to Portland is included in the model. Attributes include distances, time and speed between stations, train passenger capacity, and service frequencies.

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Route/Path Choice

Path Choice function and coefficients are contained in UTF[9]. Cost attributes (previously defined) are found in UTF[4] and UTF[6], while capacity and restraint function are in UTP [1]. The path choice parameters do not need to match the true costs used in the mode choice function found in UTF[7]. Due to limited project scope, only highway capacity will be restrained in this model. Actual freight rail travel times (which include congestion) will be used.

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Trade-to-Trip ratios

Trade-to-trip ratios translate economic trades, employee and household units, into transportation flows in the form of trips and tons of freight. The rates were developed using primarily NPTS travel data and Reebie Associates freight data. They are input to the model via the UFP file.

Industry-based transport flows. Trip rates for industry transport flows used Reebie Associates and EWITS freight flow data for through trips combined with Washington State employment levels by industry. The following assumptions were made as supported by Table 7.

- SIC commodities 1-9 were produced by Agriculture Forestry and Fishing industries;
- SIC commodities 1-14 were produced by the Mining industry;
- SIC commodities 19-41 were produced by Manufacturing;
- SIC commodities 42-50 were produced by TCPU;
- Wholesale and retail goods production assumed to be 464 tone per employee (the average of the above industries);
- External to internal truck trips assumed to generate 2,116 tons/$1M of IMPLAN imports; and
- Through truck tips assumed to generate 322 tons/$1M of IMPLAN imports.

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Using these classifications and the combined Reebie Associates/EWITS data for intrastate and internal-external traffic, tons of each value to weight transport flow category were defined for these four industries. These tons were divided by the Washington LMEA employment in each industry to generate tons produced per employee.

Table 7 – Freight Trip Rates (1995 US NPTS)

		INDUSTRY			
		Agriculture	Mining	Manufacturing	TCPU
1997 I-E/I-I Tons		**1**	**2**	**3**	**4**
Value/Weight	Low	9,265,423	10,820,524	77,089,686	35,423,068
	Mid	203,008	0	49,939,463	3,877,568
	High	0	0	5,586,221	43,346,426
1998 Employees		122,398	3,380	407,455	145,334
Tons/Employee		77.36	3,201.40	325.45	270.73

Household-based trips. Trip rates for households (commute, shopping, recreation, visiting friends & relatives, services, and business promotion) used 1995 NPTS annual person trips by trip purpose per household. Table 8 shows the trip rates used in the model (based on national averages). For the initial version of the model all income categories were assumed to have the same trip rates. This assumption can be changed in future models.

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Commute trips were applied directly as per household trip rates. All other rates were converted to person trips per employee by generating the total number of such trips per employee.

Table 8 – Person Trip Rates

	Person Trips per Household Annual (1)	Daily (2)
Commute	676	2.551
Shopping	775	2.925
Visit Friends and Relatives	314	1.185
Recreation and Other (population attracted)	983	3.709
Services (3)	1060	4.000
Business Promotion(3)	20	0.075
Total	3828	14.445

(1) Daily = Annual/265
(2) Services = 80% "Work Related Business"
(3) Services/Biz promo assumed 80%-20% split of NTPS «Work Related Business» category, services also includes personal service categories (980 trips) of «Doctor/Dentist» and «Other Family Business.»

Load Factors. Load factors refer to tons per vehicle, and passengers per vehicle (auto occupancy) in UTF [4] with assumptions summarized in the file "UTF FuperMU.xls".

Heavy truck load factors were derived from EWITS and FASTTruck weight classification by commodity combined with Reebie Associates commodities and flow. Light and medium Truck load factors were derived by assuming an average cargo volume of 100, 60, and 15 cubic yards for heavy, medium, and light trucks, respectively.

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Truck load factors are shown in Table 9.

Table 9 – Load Factors

User Mode	Flow	Tons/Vehicle
Light Truck	Mid value-to-weight	3.60
	High value-to-weight	3.41
Medium Truck	Low value-to-weight	15.50
	Mid value-to-weight	14.41
	High value-to-weight	13.64
Heavy Truck	Low value-to-weight	25.92
	Mid value-to-weight	24.02
Freight Rail	Low value-to-weight	75.95
	Mid value-to-weight	68.23

Passenger vehicle occupancies were derived from PSRC auto occupancy data and public transit vehicle capacity and load factors. Passenger load factors are shown in Table 10.

Table 10 - Vehicle Occupancies

Transport Flow	Persons/ Vehicle	Assumptions
Commute	1.14	PSRC
Shopping	1.42	PSRC
Recreation/Other	1.92	Shopping +.05
Visiting Friends/Relatives	2.42	Shopping +1.0
Services	1.28	Avg (commute, shopping)
Business Promotion	1.28	Avg (commute, shopping)
Coach Bus	22.00	55 seats 60% LF

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Connecting Transport Flows Table to Consuming Factors Table

A key feature of MEPLAN is the ability of the transport model to provide feedback to the land use model (through TAD file). The transport model generates travel disutilities (costs) for each zone pair that in turn influence business and household location decisions. In future year iterations of the model, a nested logit model is used to determine the location of business and housing changes in response to these travel costs.

Peer Review

On June 1, 2001, a Peer Review Panel provided an independent, critical assessment of the approach, methodology, data inputs and assumptions of the Cross-Cascades Corridor Analysis Project model development. Peer Review Panel members were asked to evaluate the model structure, capabilities, and data needs; to assess proposed outputs, future scenarios, overall usage; and to provide guidance for priorities for next steps in model development.

The Panel was presented with an overview of the spatial I-O model structure and its representation of the economy in the Cross-Cascades Corridor. Data inputs for each of the model components and their interactions were discussed in detail. Panel members were also briefed regarding calibration and scenario development efforts to-date. The Peer Review presentation made to the Panel, meeting notes, and formal documentation of the peer reviewer comments were documented.

Overall, Peer Review Panel members strongly concurred with the choice of spatial I-O for the model structure. The Peer Review Panel also stated that the model development effort provided a sound foundation, and that the work to-date represented a good first step for a new approach to corridor and statewide modeling in Washington State. They also felt the progress to date was impressive given the time limitations.

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After reviewing the content and inputs to model components and the early results of the modeling effort, Peer Review Panel members offered four primary suggestions for consideration in future development of the Cross-Cascades Corridor model, including:

1. **Improve Cross-Cascades model calibration** to provide reliable forecasts for the corridor, while continuing to build credibility with corridor MPOs and policy makers.

2. **Introduce land area and prices in the economy/land use element of the model.** This will permit a more accurate evaluation of industry and household location possibilities, particularly near metropolitan areas. Given the statewide nature of the model, the possibility of a surrogate measure that avoids extensive new data collection should be considered.

3. **Increase the number of zones in the model.** After reviewing early runs, it appears that overall intercity trip lengths on the highway system are too long. This appears to trace back to the large size of the zones used in the model. While some large regional or statewide models use more than 3,000 zones, it appears for the purposes of statewide corridor modeling that 300-400 zones would provide a sufficient level of accuracy.

4. **Expand the scope of the model to include all of Washington State at the same level of detail and bordering regions of neighboring states and provinces.** The number of external zones should also be increased. A broader model would allow the assessment of some trip allocations that could not be considered in the present structure of the model. For instance, it was not possible to evaluate rail freight impacts of changes to the BNSF Cross-Cascade routes because the alternative route through the Columbia Gorge was not included in the model.

In addition to these key recommendations for future development, there are also a number of more technical adjustments included in Model Development Documentation. Suggestions for technical improvements to the model include:

- Capture different values for trip rates by income group.
- Use NPTS trip rate data for both weekday and weekend travel
- Add seasonality to motor vehicle user costs
- Reconfigure income categories to break where changes in behavior are occurring
- Expand the model's treatment of transportation networks – include rail capacity impacts on the transportation system and include additional airports outside of the corridor that could have an impact on the system.
- Document model sensitivity of factors, level of uncertainty and the testing for goodness-of-fit targets
- After one or two additional iterations at the statewide level, consider some of the advantages of microsimulation for some model elements

Model Testing

After the model has been assembled it must be compared to observed "target" values. This process establishes certain key parameters that connect the various systems together, and can be used to explore the impact of the assumptions made in the model design. Calibration is a process that compares observed historical activity with model predictions, and is followed by adjustment of model parameter values, model assumptions, or model structure, until the predictions match the observed patterns as best as possible. Similarly, before using the model to predict future activity, it should be validated in order to test the model's predictive capabilities. Validation targets can include other forecasted data and elasticities. In the Cross-Cascades Corridor Analysis Project schedule, only minimal calibration and validation were possible within the project scope. Thus, the objective of the calibration/validation process, particularly as it has been applied to a real-world example of the CCC corridor, was to make initial model runs and understand the major issues of the model that would point to recommended next steps regarding available target data, model parameters, and shortcomings in model assumptions and structure.

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Baseyear Calibration

In most transportation modeling work, calibration is an ad-hoc process of manually examining model outputs and comparing them with data and expectations. In this project, a more formal process was adopted. A collection of data items were identified as «targets», and an algorithmic process was used to adjust parameters to attempt to meet those targets. This process identified parameter values, and provides a framework for investigating lack-of-fit and guidance in changes to the model assumptions and model structure.

A set of targets of historical observations for the Cross Cascades Corridor were collected for calibration. The targets are generally transportation demand related, describing the amount of travel by different modes over different distances or origin-destination pairs.

The collected targets span the following types of data:

- Trip length distributions
- Mode splits
- O-D trip tables
- Demand elasticities
- Road or station counts

To assist in the calibration of highway trip patterns and demand, the project team synthesized an O-D highway trip table from WSDOT's 1998 Travel Delay Methodology roadway volumes.

Within the Cross-Cascades Corridor Analysis project scope, initial calibration was begun. The team made use of MEPLAN calibration software, previously developed by John Abraham of the University of Calgary [ref], to simultaneously calibrate the multidimensional problem of modifying multiple MEPLAN parameter values to match a myriad of target values in calibration of baseyear MEPLAN output. The calibration software requires user inputs of: MEPLAN parameter values to be altered; baseyear targets to match (e.g., trip length distributions, mode splits, O-D), and target weights that reflect the relative importance of the (potentially conflicting) targets. The initial base year Cross-Cascades Corridor MEPLAN model calibration efforts, using the calibration software, were set up to match passenger and freight targets of: average trip lengths by flow and mode, and mode split by flow. Passenger targets were derived from a weighting of ATS (trips greater than 100 miles) and NTPS data (all trips) for Washington State, while freight targets relied on the Washington State Reebie Associates freight data.

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The process of calibration assists analysts in better understanding the data as well as the validity of the model and findings. These findings are included later in this report.

Model Validation: Four Scenarios

The model was tested by running four hypothetical scenarios designed to demonstrate different aspects of the model capabilities and outputs. The results of the scenarios form initial validation of the predictive capability of the model. It should be noted that because of limited model calibration of the baseyear, the ***scenario results should only be used for demonstration purposes***. Specific lessons learned are identified in the following section.

The four scenarios evaluated in the Cross-Cascades Corridor model include:

1. **No Build.** This scenario introduced no changes to the transportation system except those included in the State Highway System Plan under the constrained financing alternative. Economic and demographic changes were allowed unconstrained.

2. **Significant increase in transportation costs: doubling vehicle operating costs.** Under this scenario the operating cost of highway vehicles, including cars, buses and trucks, were doubled. The purpose of this was to demonstrate the applicability of the model to testing user or cost assumptions.

3. **Major economic expansion in Eastern Washington.** This scenario added 10,000 manufacturing jobs in Eastern Washington along the Columbia River and in Spokane. All jobs were identified as exogenous (export) industries. The purpose of the scenario was to demonstrate the ability of the model to identify transportation impacts of such a change as well as secondary economic and demographic impacts.

4. **Major improvement to the transportation system.** The purpose of this scenario was to test the impact of a major investment to the highway capacity characteristics of SR-2, and determine whether any transportation demand, economic, or demographic shifts would occur. The attributes of SR-2 were significantly changed to match the travel times and capacities available on I-90.

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In testing the model, each of the scenarios were evaluated by comparing impact on:

- Employment by zone
- Households by zone
- Traffic volumes on I-90 and SR-2

An attempt was also made to evaluate mode split, which was not possible because of the limited calibration process used by the team. Better specification of constraints and system characteristics along with more complete calibration will improve future model updates. This subject is covered in more detail in the following section, Lessons Learned.

Future Employment Allocation: Outcomes for employment are compared in the four maps of Figure 11. With regard to employment growth, the analysis of the scenarios demonstrated that the model is working and reallocating employment growth in response to changes in transportation costs, major transportation improvements and changes in exogenous employment. There is a notable anomaly in the baseyear with regard to Spokane and Kootenai counties reflecting inadequate baseyear calibration (see section on Lessons Learned). Despite this anomaly, employment behaves in the model as expected when the various scenarios are compared. Increased transportation costs (Scenario 2) resulted in a general concentration of employment. In general, increases in exogenous employment (Scenario 4) resulted in multiplied increases in total employment as would be expected in an economic model. For instance, the imposed 591 manufacturing exogenous employees in the Wenatchee zone in 2004 led to an increase of 1,272 total employees by 2019. Major improvements to SR-2 (Scenario 3) resulted in positive, albeit small, changes in employment on that facility.

Future Household Allocation: A comparison of households by zone is contained in the four maps of Figure 12. As expected, the changes in the number of households by zone follows closely the changes in employment. Because the model allows for commuting between zones there are cases where household growth lags or exceeds employment growth. The loss of jobs in Spokane, in particular, is attributed to a significant number of workers commuting to King County in the baseyear, and their subsequent movement west to reduce their commutes (see more detail in Lessons Learned).

Future Traffic Volumes: Figure 13 illustrates the future traffic loads for all roadways in the model, while Figure 14 isolates the changes in traffic along I-90 and SR-2 within the Cross Cascades Corridor. The level of traffic is obviously overstated (discussed below in

Lessons Learned), however, the changes in traffic volumes in the various scenarios are generally logical and provide insight to how the model is estimating effects of changes to coefficients, networks, etc.

Under the Significant Increase in Transportation Costs Scenario (Scenario 2), statewide loadings indicate an overall decline in traffic volume relative to the No Build Scenario (Scenario 1), although some segments of I-90 and SR-2 show increases in traffic demand. Further study will be required to understand this result, which could be either an anomaly related to inadequate calibration and specification of constraints, or a result of interaction of transportation and economic factors.

Increasing employment in Eastern Washington (Scenario 3) did not result in increased traffic on I-90 and SR-2. A plausible cause for this is that the model is missing constraints that limit commuting trip lengths, thus, the anomalous Spokane to King County commutes of the baseyear are reduced by the increased employment in Eastern Washington zones. More study and better calibration will be required to fully understand this.

Improvement of the capacity and travel time of SR-2 (Scenario 4) had interesting effects on traffic volumes, including an overall reduction in travel along I-90 and significant increases in traffic demand on specific segments of SR-2.

The conclusion of the scenario testing process found that the model is working and responds to the proposed scenario policy questions in its predictions of future economic and travel activity. Users should be cautioned, however, that the results cannot be properly interpreted until the model is fully calibrated.

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Lessons Learned

Calibration and validation, as discussed earlier, form the foundation for understanding the spatial economy of the corridor and how transportation demands result and impact economy and land use development. In the brief testing of the model, several items of interest were noted that suggest changes in target data, model assumptions, and model structure. Other items are insightful as to the nature of the spatial economy of the corridor/state. These are summarized below with specific examples:

Model Targets

The model targets consist of a conglomeration of limited and inconsistent data sources. The inconsistency and lack of intercity focus of these targets, particularly for passenger travel, resulted in mode splits that were dominated by the air mode. Passenger data, in particular, relies on national data sources with little local detail, and it was difficult to combine the ATS (trips over 100 miles) with the NPTS data to fully represent the intercity trips. Additionally, for freight, although the Reebie Associates TRANSEARCH data was a valuable and comprehensive data source, it is itself an input-output based model of freight transport. A statewide household O-D survey or similar smaller efforts would provide valuable insight into intercity passenger travel (e.g., traveler attributes, and travel modes, frequencies, trip lengths). Similarly, a comprehensive database of statewide freight flows, such as that provided in the EWITS data, should be obtained and maintained by the state.

Model Assumptions

Fixed Economic Relationships. The Cross-Cascades Corridor model results indicate that the Washington State spatial economy cannot be well represented using fixed relationships between industrial output ($), employees and households, as assumed in this project. More information needs to be collected about how the economy differs in different regions leading to more elastic relationships sensitive to costs, prices, and job/labor availability. More detailed travel data can also help to determine how the economic relationships vary across the state.

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High Travel Loads. The loads on the transport networks, and on highways in particular, are too high. Several potential causes of overestimated traffic volumes are:

- Trip lengths are too long (e.g. on forced long commutes due to fixed economic relationship);
- Trip generation rates per employee or household are too high; and
- Network coding of intrazonal trip and flow generation functions (non-commmuter style) may need improvement.

Capacity Restrictions. The Cross-Cascades Corridor model did not impose highway capacity restraints during the assignment process. Accounting for highway capacity should produce more stable traffic loads along the corridor, as it appears traffic is diverted off SR-2 and/or I-90 at locations where more capacity restricted alternatives are available (e.g., urban areas).

Vehicle Loads and Trip Rates. Better information on freight shipment size and smaller vehicle movements and services trips (e.g., office supplies, business trips) would be useful to better represent freight flows in the model. This could be achieved through an Establishment Survey, which surveys selected business about their transport activity over a representative period. [[20]] Better information on trip rates might also be found from the "Make" and "Use" tables that often accompany input-output data. Such tables identify the commodities produced (Make Table) and used (Use Table) by each industry. The team also has access to an aggregate spatial I-O model component that could replace portions the MEPLAN land use/interface functions, which more directly models freight and imports/export using Make and Use Table data. This method is currently being used in Oregon statewide travel demand forecast model.

Freight Complexity. The nature of freight in the state of Washington is complex, and may not adequately be represented in the Cross-Cascades Corridor model. This includes logistics and fares of freight travel, intermodal connections, and port activities. More direct representation of the diversity freight movements rather than average costs and shipment size, can be made by using a statistical distribution to more accurately reflect actual freight diversity. Such a characterization might require microsimulation approach. Additionally, because rail transportation (freight and Amtrak) is near capacity and imposes delays, it may be desirable in the future to account for rail capacity restrictions in the model. This is complicated by the difficulty in defining the meaning of capacity and pricing for rail.

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External Trips. The model is set up to endogenously model intrastate and internal-external freight trips. However, external-internal and through truck trips were added as special flows. Because through freight trips are a large part of the corridor traffic mix (e.g., traffic to/from the Ports), it would be desirable to incorporate external rail and air freight trips. Additional data could also improve the assumptions made regarding the special external truck trips.

Model Structure. The Cross-Cascades Corridor model results indicate that more and smaller zones would better represent the study area. The large size of the Cross-Cascades Corridor model's zones are not fully consistent with the assumptions made about trip and trade relationships. Additionally, large zones make it difficult to load the roadways adequately and to achieve the short average trip lengths represented by the calibration targets. Another option to account for the large number of shorter trips would be to adopt the special treatment of intrazonal trips available in the prototype MEPLAN version 4, which allows a distribution of intrazonal trip lengths within a single zone. Finally, areas of the state, including competing corridors, should be represented to adequately model the available trade-offs.

Future Model Development

During both the model development/testing and peer review process, a number of suggestions were generated for improvement in future modeling efforts. These are presented as incremental to the basic structure of the spatial I-O approach that was overwhelmingly supported for statewide modeling during each step of the process.

All of the suggestions are assumed to be possible within the MEPLAN or extended spatial I-O model structure begun under this project. Additionally, the comments are also geared toward expanding the model to a statewide level, rather than a corridor-by-corridor approach. This would allow all future corridor efforts to benefit from the comprehensive view of their function within the larger statewide system, and more accurately account for the impacts of competing corridors.

Future Model Development

The major recommendations for future model development are summarized below. In addition to these major recommendations, a number of other technical suggestions resulted from comments at modeling workshops and project team experience.

Short-term Recommendations

1. **Improve Calibration of Existing Model.** Further work in calibrating the existing model would provide reliable forecasts for the corridor, while building credibility with corridor MPOs and policy makers. Additionally, this calibration step will provide invaluable insight (e.g., see the lessons learned section of this document) regarding the spatial economy of the State and its relationship to statewide transportation demand that would be useful in further model development.

2. **Incorporate Land Use.** Introducing land area and prices in the economic/ land use element of the model will permit a more accurate evaluation of industry and household location possibilities, particularly near metropolitan areas. Given the statewide nature of the model, the possibility of a surrogate measure that avoids extensive new data collection should be considered.

3. **Allow for Elastic Economic Relationships.** This involves allowing the technical coefficients in the input-output model to vary with prices and utility. The initial assumption in the model design was that the interrelationship between different factors was constant across the State. In calibration, it became apparent that there are important differences between areas of the State. For example, in the Seattle area there is substantially more industrial production per capita. The assumption that employee productivity is equal across the state (constant employees/ $ by factor) and that labor participation was essentially equal (constant employees/ household by household category) led the model to generate a less than realistic east-to-west commuting pattern.

4. **Increase the Number of Zones.** After reviewing early model runs it appears that overall intercity trip lengths on the highway system are too long. This appears to trace back to the large size of the zones used in the model. While some large regional or statewide models use more than 3,000 zones, it appears for the purposes of statewide corridor modeling, 300-400 zones would provide sufficient accuracy.

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5. **Expand Model Scope.** It is recommended that the model be expanded to include all of Washington State at the same level of detail and border regions of neighboring states and provinces. The number of external zones should also be increased. A broader model would allow the assessment of some trip allocations that could not be considered in the present structure of the model. For instance, it was not possible to evaluate rail freight impacts of changes to the BNSF Cross-Cascades routes because the important alternative through the Columbia Gorge was not included in the model.

Long-term Recommendations

1. **Better Washington State Data.** The model was constructed with national data on personal travel, and the calibration process determined that these data are not completely appropriate for Washington State. Additional supplementary primary data collection regarding the travel of people and goods in Washington State would improve the model performance and credibility. For example, more specific data on commuting trip patterns (i.e., a household O-D survey) could be used to calibrate the travel model *and* could help to establish the variability of some technical coefficients as described above. Also, an Establishment Survey, which surveys selected business about their transport activity over a representative period, would be helpful in better understanding small goods movement and service trips.

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